Critique of the Lapreau 2 Environmental Impact Statement and the Responses To It Concerning Radionuclide Releases and Their Potential Controls

R.E. Jervis (Toronto)

Ph.D., P.Eng., F.C.I.C.

Nuclear and Radiochemist

University of Toronto

and

Consulting Chemist

Chemical Engineering Research Consultants Ltd.

Toronto, M5S 1A4

Consultants Report to the

Federal Environmental Assessment Review Office

Hull, Quebec, K1A 0H3

October, 1984

CONTENTS

	Page
Summary	i
Introduction	1
Conclusions and Recommendations	4
1. Adequacy of the EIS	4
2. Tritium	5
3. Noble Gas Nuclides	6
4. Liquid Radwastes	7
5. Carbon-14	8
References	10

SUMMARY

A review has been made of the Lepreau 2 Environmental Impact Statement (EIS) and various responses to the EIS filed with the FEARO office, particularly with respect to environmental radionuclide emissions, their impact and potential control measures.

In this consultant's opinion, the proposed Lepreau 2 installation, environmental controls and associated safety analyses have been based largely on up-to-date methodologies valid in 1984. Two possible deficiencies are the neglect of future provisions for tritium control, and, a failure to assess the relative impact of potential carbon-14 emissions. Since the projected environmental impacts and detriment resulting from likely radioactive emissions would probably be acceptable under current reactor safety regulations and international ICRP recommendations, the matters at issue are whether additional emission control technologies ought to be deployed if it can be demonstrated that further marginal reductions in environmental emissions can be achieved at the expense of modest additional capital and operating cost expenditures. Although it is alleged that the said additional control technologies now make it possible in the mid-80's to further reduce radionuclide additions to the environment, the technologies involved are not new and have been available as design options during most of the last 10 - 20 years if such marginal reductions of emissions had been judged to be desirable, to be required, or seen to be consistent with the requirements of the ALARA criteria.

Comments are appended also to this report concerning a number of apparent deficiencies in the EIS report and Supplement.

Recommendations:

After assessing various sources of information on the possible levels and environmental impacts of radionuclide emissions particularly tritium, noble gases, liquid radioactive effluents and certain long-lived nuclides such as carbon-14 and I-129, the following conclusions have been reached:

(i) Tritium losses both to the atmosphere and to liquid effluents are likely to constitute one of the regular, significant discharges from Lepreau 2, will increase each operating year and be readily detectable both on and off-site. Although not a prominent bioaccumulator or food chain transfer candidate, tritium will represent an increasing contribution to the boundary dose and one that may become comparable after 10 or more years to all other emissions if no controls are used. Design provision should be made to allow the option either for on-site tritium removal from moderator heavy water or for its transport for the purpose of processing to Ontario about 5 to 10 years after startup. This option should be pursued particularly if it becomes clear that dual-purpose heavy-water upgrading, T-removal is desirable for occupational exposure control, or, that such facilities will be required at the Lepreau site eventually for decommissioning. However, it would seem inappropriate at the present time to require a decision on a Lepreau T-removal system while plants for two alternate processes are being built in Ontario, permitting comparison and performance experience to be gained with the two processes. The technology for T-removal and safe handling is relatively complex and costly.

(ii) Noble gas emissions which, at Lepreau 1 occurred only sporadically and which by their nature pose a slight external radiation hazard in populated areas and can be readily monitored by area TLD's, should not require further reduction such as could be achieved by the use of delay tanks. The control technology is costly for the marginal benefit derived, is not effective for long-lived noble gases such as Kr-85, and the critical population in this case is more readily controllable.

(iii) Liquid effluent radionuclides are diluted into station cooling water for disposal at CANDU stations, the most significant of which are radioiodines as judged from their contributions to DEL (derived emission limits), and are to be monitored and recorded before discharge from Lepreau-2. An opportunity exists alternately,

to collect such liquid radwastes, arising as they do in relatively small volumes, concentrate and solidify them as a means of disposal, preferably at a designated waste disposal repository off site. The quantities of radionuclides in liquid radwastes at other CANDU stations are relatively low and as discharged from holding tanks are only marginally more concentrated than a 100 Bq/L MAC drinking water standard and are well within licensing guidelines as well for total quantity discharges. Nevertheless, considering the range of fission product and neutron activated nuclides contained in the radwaste together with tritium, and the possibility for their incorporation in marine organisms, food chains and sediments once discharged to the offshore waters, the opportunity for collection and disposal after treatment is an attractive alternative.

In principle, in this consultant's opinion, the current practice of disposing of liquid radwastes is acceptable environmentally and should not of itself require treatment. However, if, as suggested by the decommissioning plan enclosed as appendix B of the ERI, a liquid waste treatment unit may be installed for consolidation of radionuclides arising during decontamination stages of Lepreau decommissioning, it could be advantageous to install and operate the unit during the operating lifetime of the reactor(s) as an alternative to off-shore disposal of liquid radioactive effluents notwithstanding the appreciable capital and operating costs entailed.

Additionally, low level emissions of long-lived I-129 to liquid effluents could also be avoided by such collecting of all liquid radwaste arisings in the plant(s) - a single radwaste processing unit could serve both reactors at Lepreau.

(iv) The proponent states in the EIS report that all radionuclides that potentially could be released were considered in the safety analyses and DEL estimates. However, gaseous emissions of carbon-14 which have been encountered at other CANDU sites and for which provisional DEL's have been established, were not referred to. If such pathways analyses and DEL estimate together

with emission monitoring at Lepreau 1 establish that C-14 emissions are likely to constitute a relative contribution to total site DEL comparable to that of other emissions (and even though CO_2 moderator cover gas is used at Lepreau), provision should be made for C-14 control such as cover gas treatment with $Ca(OH)_2$. The estimated $0.25 million cost, even if a slight underestimate of 1987-88 installations costs of such controls, would be well justified in terms of the reduction in environmental detriment so readily achievable. On the other hand, based on present available information it is unclear whether AECL reactor licensing requirements would require C-14 removal at a Lepreau 2.

In the consultant's report that follows the information taken into consideration in reaching these conclusions (or, opinions) is outlined together with estimates of some possible levels of radionuclide emission and comments on the costs involved in the several radionuclide emission control measures proposed.

INTRODUCTION

Among the issues identified in some responses to the Lepreau 2 Environmental Impact Statement (EIS) and which were of interest in this study were the following:

(i) whether the Lepreau 2 safety analysis and proposed control technology for radioactive emissions has been essentially 'frozen' at a stage prior to Lepreau 1 (circa 1975) and should have been updated in the light of new technology, new standards and codes [1,2],

(ii) whether the fact that Maritime Nuclear overlooked potential problems from certain long-lived radionuclides: C-14, Kr-85, I-129 is an important deficiency in the EIS [1],

(iii) whether Maritime Nuclear should be required to install additional emission control devices to reduce further, emissions from tritium, noble gases, C-14 and liquid radwaste nuclides [1], and

(iv) whether the Lepreau site post-operational environmental monitoring program adequately assesses the radiological impact on the human population [3].

A basic issue underlying these and other similar questions is whether the proponents of Lepreau 2 should be required to meet more stringent environmental controls than any other operating CANDU unit even though Maritime Nuclear proposes to use current abatement technology and the resulting environmental radiological doses are likely to be within accepted national [4], and international standards [5]. The ALARA criteria applied by the proponent that result in predicted levels well below 1% of derived emission limits is contrasted with an environmental improvement general criterion that requires that emissions be reduced further by introducing additional control technology available at modest cost even though the evidence suggests that the marginal reduction in environmental detriment may be made to an impact that is already barely detectable or very significant. The extent to which this is actually the issue in deciding on the virtue of requiring additional emission controls at Lepreau varies somewhat with the particular radionuclide, its sources of emission and fate.

In arriving at a series of conclusions and recommendations as to whether there were deficiencies in the Lepreau 2 EIS document or in the proposed plant design with respect to radioactive emissions, a variety of documents and sources of information were reviewed, including: the Lepreau 2 EIS [6], Supplement (of Sept. 17/84 [7], and supporting documents [8]), the compendium of comments submitted to FEARO [9], and particularly, the N.B. Environment Study Advisory Group Report [3], the Environment Canada submission [1] together with a series of reports, papers and computer modelling results [10-12] that had provided the major technical basis for the Environment Canada recommendations, plus the BIO PLEMP (1982) report [13]. Information and specific opinions were sought by this consultant on key points regarding tritium removal technology [14], carbon-14 sources and environmental emissions from CANDU's [15], liquid radwaste treatment and noble gas emissions [16], from scientists and engineers of Environment Canada, Ontario Hydro, AECL and the AECB.

Previously, and in other capacities, this consultant has had occasion to review with NBP health physics staff, N.B. Depts. of Health and of Environment and the Radiation Protection Branch, Health and Welfare Canada, the specific plans and rationale of the Lepreau 1 pre-operational environmental monitoring program [17]. In addition, several visits were made, during the last 20 years, to liquid radwaste treatment units in Canada, Japan, S.E. Asia and India. Environmental research in the University of Toronto radiochemical laboratory during the period 1972-1980 has included measurements of radionuclides in the vicinity of a CANDU plant; especially for short-lived fission products and for tritium, and assessment of C-14 content in moderator. Current research involves studies of radioiodine behaviour in reactor coolant streams.

In this consultant's opinion, none of the substantive matters being addressed concerning radionuclide losses to the environment at Lepreau 2 are new in 1984, or are unique to the Lepreau site. Nor are the control technologies suggested really new, although probably better design and performance data and more current cost estimates are available at present than were available at earlier times during the last decade or so when the control technologies arose. In this respect, the issues to be resolved are very little different in type or in detail to those

which were considered for any recent CANDU installation, including Lepreau 1. To the extent to which this is a valid assessment of the situation, a major consideration for the Environmental Assessment Review Panel is: what aspects of radiological environmental impact of the present Lepreau 2 proposal require these questions to be faced or resolved in a different way than in the immediate past? It would seem that the underlying issue to be resolved by the Lepreau 2 EARP panel is whether further reductions in environmental detriment should be required simply because they can be accomplished at acceptable cost and in the interests of reducing to the 'technologically possible minimum', insults to the environment.

In the sections of the report that follow the individual topics studied are outlined with supporting data and the conclusions and recommendations cited.

CONCLUSIONS AND RECOMMENDATIONS

1. Adequacy of the EIS:

A study of the Lepreau 2 Environmental Impact Statement (plus the September 84 supplement) indicates to this reviewer that the safety analyses performed and the emission abatement systems proposed to limit radioactive losses to the environment are generally thorough and up-to-date. Two limitations in the proposal are: (i) inadequate consideration of the need for possible future tritium emission controls and (ii) a failure to include reference to potential carbon-14 emissions to the atmosphere and their likely significance.

As stated by Maritime Nuclear in their EIS supplement, recalculation of DEL's (derived emission limit) using the few new data on significant transfer coefficients and improved gaseous dispersion models, would yield values not significantly different than those derived for Lepreau 1. Furthermore, a proponent cannot be expected to base safety analyses and calculations on future guidelines or proposed revised standards before they are formally adopted. In any case, it should be noted that the proposed CSA code [18], for the computation of DEL's will only be, best, a 'consensus standard'. 'Consensus standards' are those which are drafted by designers and practitioners to represent the common practice, or consensus, in going about a given procedure or design, and government and other members of such drafting groups are invited to make comments. As such, a consensus standard has no official status for use in regulating or licensing a proposed system unless the regulator, such as the AECB in this case, decides to cite it, or require it, for use in a licensing guide.

Overall, and noting the exceptions mentioned above, there appears to be little else that Maritime Nuclear could have measured or ought to have considered in their Lepreau 2 environmental assessment and in support of their contention that an adequate degree of radiological safety has been embodied in their proposed plant design.

2. Tritium:

Emissions of tritium and tritiated water to the atmosphere and to liquid effluents is a particular attribute of pressurized heavy water reactors and such emissions continue to occur even from new plants despite high standards of leak-proofing and containment. Moreover tritium losses increase with the age of the reactor due to tritium buildup in the moderator and coolant. Conservatively, it has been estimated based on much PHWR operating experience that a typical CANDU 600 emits 10^{14} to 10^{15} Bq/a [12] and which typically amounts to much less than 1% of its DEL. While tritium concentrations significantly greater than detection limits can regularly be found in environmental samples in the vicinity of a CANDU, the contamination levels are marginal and are unlikely to be exacerbated by natural processes since T (tritium) is not prone to bioaccumulation or other processes of concentration.

Therefore there seems to be little necessity for requiring measures to further minimize tritium losses such as processing for tritium removal from reactor heavy water unless it can be accomplished together with a plan for heavy water upgrading such as may be required for restriction of occupational T exposures. In any case it would be unlikely that T removal is required within the first five years of reactor operation or until the moderator system exceeds a T concentration of 10 Curies (Ci)/kg. It should be noted that, were it decided as an alternative to on-site T removal to ship irradiated heavy water to Ontario for T removal, that the specifications for transportation containers permit shipments of water with less than 10 Ci/kg with much less stringent container specifications than for water of higher T content [14].

An important consideration for Lepreau is that tritium removal processes are relatively complex and costly and are under current development in Canada. Two different plants are under construction in Ontario: an Ontario Hydro Darlington plant will be based on a French process while a demonstration plant being constructed at Chalk River is based on a process pioneered by AECL [14]. While the latter plant will cost about $10 million, the Darlington plant will cost in excess of $50 million and it is probably on this basis that it has been suggested that a possible tritium removal unit for Lepreau might cost $60 million.

Since tritium losses can constitute a significant and increasing contribution to off-site radiation dose and in view of the prospect that any tritium removed from Lepreau heavy water could possibly be marketed for up to $0.90/Ci or nearly $10 million/kg, a requirement for T removal capability at Lepreau could be well justified. However, it would seem premature to require a commitment for T removal at this time but instead to recommend that design provision be made to permit T removal in five to ten years. When the T removal processes have been better evaluated and when the credit value of the removed tritium is an uncertain world fusion market might be clearer, a better ALARA decision concerning tritium can be made. Otherwise the marginal improvement in boundary radiation dose gained by tritium removal down to a steady state moderator concentration of 5 Ci/kg would not be warranted of itself.

The latter opinion could be further clarified when additional information on tritium dispersal in the waters off Point Lepreau is derived either through continued monitoring or through deliberate tritium discharge carried out to facilitate tracer dispersion studies [7].

3. Noble Gas Nuclides:

A recommendation has been made by Environment Canada [1] that noble gas emissions be reduced by a factor of at least 10 by employing charcoal-loaded delay tanks at a capital cost of from $3 to $8 million. Further, there was a suggestion that consideration should have been given in the EIS to emissions of long-lived Kr-85 even though (i) it can be shown that it constitutes less than 10^{-4} of noble gas emissions and an even smaller fraction of population dose, (ii) more importantly, because of its long half-life, it would not be reduced by deployment of a noble gas control system [10].

It was noted that, during the period in 1983 for which Lepreau 1 release data were provided, noble gas emissions were only detectable during 7 weeks out of a 25 week monitoring period and their estimated contribution to DEL was 2.4×10^{-3}%. The radiological hazard resulting from noble gas emissions is that of direct radiation exposure by the gaseous plume and they contribute most significantly to an individual spending 168 hours/wek at the plant exclusion boundary. The population

density adjacent to Lepreau is particularly low so that further dose minimization achieved by noble gas controls would scarcely be warranted. Therefore it is concluded that noble gas emissions control is not warranted.

Kr-85 (10.8 y half-life) cannot be considered to pose a serious long term contaminant in the vicinity of Lepreau but it can contribute to general global concentration increases over periods of about 50 years.

The cost estimates for installing charcoal-laden noble gas delay tanks are probably over-estimated as a set of such holding tanks to operate at ambient temperature could probably be installed at a lower cost.

4. Liquid Radwastes:

Liquid effluent radionuclide releases, the most significant among which at Lepreau 1 is radioiodine based on fractional DEL, are regularly collected, diluted into cooling water flow and amounted to about 25 - 30 Ci/mos tritium and 10 mCi/mos of other mixed radionuclides during the mid-1983 period reviewed in the EIS. Since the liquid radwastes were incorporated in a mean volume of about 1500 m^3/mos, typical radionuclide content of the waste diluted into cooling water was itself about 6 $\mu Ci/m^3$ or 6 pCi/cm^3, a concentration only slightly above a 100 Bq/L MAC drinking water standard. National radioactive effluent controls specify in addition to MAC (maximum acceptible concentration), maximum total permissible monthly releases in order to prevent large liquid radionuclide releases if fortuitously large water flows, such as the once-through reactor coolant is available to provide large dilution factors. However, the monthly total releases are typically well below licensing limits.

Unlike emissions to the atmosphere, the type of radionuclides discharged to off-shore waters are more likely to become incorporated in marine organisms, foodchains and bottom sediments. While several nuclides contribute to external radiation dose to persons engaged in clam digging or dulse gathering, radioiodines which constituted the largest contribution to DEL in 1983 at Lepreau, can make a significant contribution to internal exposure of human populations. No mention is made in the EIS of

the long term significance of low level I-129 emissions or of a DEL estimate for I-129. Although it is not expected that I-129 releases from reactor fuel will be comparable in magnitude to those of I-131, some consideration should have been given to its potential significance because of its long lifetime and tendency to bioaccumulate.

Undoubtably the current practice of disposing of liquid radwastes routinely by dilution into Bay of Fundy off-shore waters is quite acceptible environmentally and should not of itself require special waste treatment. However, if, as suggested by the decommissioning plan provided as appendix B of the EIS, a liquid waste concentration and solidification unit may need to be installed for treatment of liquid radwastes during the decontamination stages of decommissioning, it could be advantageous to install and operate such a unit during the operating lifetime of the Lepreau reactors for treatment of radioactive liquid wastes as an alternaive to dispersal into the local aquatic environment. The estimated cost of $5 million capital and $1 million/a operating is entirely realistic for a treatment unit capable of achieving up to 10^4 decontamination factors. Radwaste treatment plants visited several years ago, while capable of processing several hundred litres per month to D.F. of about 100 had capital costs considerably less than $1 million.

Based on the above considerations, it would be sensible, but not imperative, not to delay until decommissioning a plan to install a liquid radwaste treatment plant capable of concentrating effluents from both reactors with the objective of eliminating most routine releases to the coolant discharge and concentrating liquid waste arisings, instead, for eventual solidification or bitumenization as a means to facilitate off-site disposal.

5. Carbon-14:

The proponent states that all radionuclides which potentially could be released had been considered in DEL estimates and in emission and environmental monitoring. However, initially, no reference was made to carbon-14 whose emissions have been observed at other CANDU sites, and for which, provisional C-14 derived release limits have been established.

Experience to date indicate that emissions from the moderator cover gas system to the atmosphere are of the order of $3 - 5 \times 10^{11}$ Bq/a from CANDU's using CO_2 annulus gas, such as Lepreau 1 and 2 reactors [12], whereas release rates greater by a factor of 10 to 40 resulted when nitrogen gas was used. Except for the latter cases, gaseous C-14 emissions were estimated to constitute about 0.01 to 0.1% of the provisional release limit, a contribution greater than that estimated for other gaseous emissions. Surprisingly, Maritime Nuclear refer to the potential release rate of about 0.1% as "too small a fraction of the DEL to make it worthwhile" [7] to consider C-14. A release rate of this order would make C-14 emissions the largest single contributor to population dose, if indeed such estimates were valid for Lepreau.

Carbon-14 losses to liquid effluents can be almost completely eliminated by the routine moderator purification systems. Carbon-14 is not likely to accumulate in reactor systems with time because it is continuously removed by a number of processes.

The above considerations would suggest that measures to reduce C-14 emissions should be undertaken. If a pathways analysis for Lepreau 2 and DEL estimate reveal that C-14 emissions at the levels reported for other recent CANDU plants are likely to constitute a fractional DEL comparable to that of all other emissions, provision should be made for C-14 removal from moderator cover gas. The estimated cost of $0.25 million for calcium hydroxide cover gas treatment, even if an underestimate of 1987-88 installation costs, would be well justified for the appreciable reduction in environmental detriment that could be so readily achieved.

REFERENCES:

[1] Environment Canada, "Review of the Lepreau 2 Environmental Impact Statement", August 1984.

[2] Fisheries and Oceans Canada, "Technical Review of Point Lepreau II Nuclear Generating Station Environmental Impact Statement", July 1984.

[3] Environment New Brunswick, "Report of the Study Advisory Group for the Lepreau II Environmental Impact Assessment", August 1984.

[4] Atomic Energy Control Board (AECB), Radiation regulatory limits; reference the Atomic Energy Control Act (Canada), 1971.

[5] International Commission on Radiological Protection (ICRP), "Annals of the ICRP 1(3)", ICRP Publication 26 (1977).

[6] Washburn & Gillis Associates Ltd., "Lepreau 2 Environmental Impact Statement", prepared for Maritime Nuclear, May 1984.

[7] Washburn & Gillis Associates Ltd., "Lepreau 2 Environmental Impact Statement - Supplemental Information", prepared for Maritime Nuclear, September 1984.

[8] N.B. Power, Supporting documents no. 1 (2)a, b, c, no. 1 (9), no. 1 (13) and no. 1 (14) submitted September 1984 with EIS Supplement.

[9] Environment New Brunswick, "A Compendium of Comments on the Lepreau II EIS", August 1984.

[10] R.J. Tosetti, "Gaseous Waste Treatment", presentation to the ASME Radioactive Waste Management Course, Alexandria, VA, May 1984.

[11] P.G. Finlay, R. Christensen, J.D. Muir, D.W. Draper, "Radioactive Liquid Wastes from Steam Electric Generating Stations", internal draft report of the Power Generation and Energy Div., Water Pollution Control Directorate, Environment Canada, 1982.

[12] OECD Nuclear Energy Agency Report, "Radiological Significance and Management of Tritium, Carbon-14, Krypton-85, Iodine-129", R.V. Osborne, editor, ISBN 92-64-12083-1, 1980.

[13] J.N. Smith, K. Ellis, F.J. Bishop, PLEMP Report, "Pre-operational Environmental Monitoring Report for the Point Lepreau, N.B. Nuclear Generating Station", Can. Technical report of Hydrology and Ocean Sciences, No. 4, 1982.

[14] AECL/CRNL, personal communication from Development Chemistry Staff, AECL, Chalk River, October 1984.

[15] Ontario Hydro, personal communication from health physics staff, Safety Div., Ontario Hydro, October 1984.

[16] Atomic Energy Control Board (AECB), personal communication from staff of the AECB Licensing Directorate, October 1984.

[17] AECB Environmental Monitoring Advisory Committee, review of Lapreau 1 environmental monitoring program, 1977.

[18] CSA Standard N288.1 (draft), "Guidelines for Deriving Release Limits for Radioactivity in Gaseous and Liquid Elements for Normal Operation", 1984.